NON-RIGID CONTINUOUS MOTION CORRECTION IN ABDOMINAL IMAGING

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Target audience: Clinicians working on abdominal diagnosis and scientists interested in motion correction for MRI.

Purpose: In abdominal imaging, diagnosis information might be damaged due to non-rigid and continuous motion artifacts, which can be caused by breathe and intestinal peristalsis movement. Data Convolution and Combination Operation (COCOA) method has been proposed to detect non-rigid random motion artifacts by checking the consistence between the synthetic and acquired data set [1].Rigid motion between different strips can also be effectively eliminated using PROPELLER[2]. However, how to combine these two methods to correct non-rigid continuous motion artifacts has not been reported. In this work, we use COCOA to detect and discard motion corrupted data under PROPELLER trajectory, then use SPIRiT to reconstruct the k-space.

Methods:

Motion correction process: In COCOA, k-space signal from multiple coil elements can be approximated by a linear combination of adjacent signals with different weights, which are called convolution kernel [1].In PROPELLER, data acquired in different strips is rotated by different angles to cover k-space. Oversampling in the center of k-space makes these data less sensitive to motion, similar to the effect of multiple images averaging [2]. Thus, central k-space data can be used as calibration to train convolution kernel. The schematic diagram of the proposed method is shown in Fig.1. The steps are summarized as follows:

1. For k^{th} strip S_k, we correspondingly rotate the calibration by the same angel to match the strip and then kernel W_k can be trained.
2. Synthetic strip S_k' can be generated from parallel imaging method while convolution kernel W_k is obtained.
3. The difference between original strip and synthetic strip can be expressed with convolution difference ΔS：

$$\Delta S = \sum_{j=1}^{m}\sum_{i=1}^{n} | S_{i,j}^{'} - S_{i,j} | \qquad (1)$$

where *m* is the number of coils and *n* is the number of data in frequency encoding direction. Motion within one strip can be detected by two parameters *err* and *var*, which are derived from convolution difference:

$$err = \Delta S / \sum_{j=1}^{m}\sum_{i=1}^{n} | S_{i,j} | \qquad (2)$$

$$\text{var} = \sqrt{\frac{1}{mn-1}\sum_{j=1}^{m}\sum_{i=1}^{n}(\Delta S_{i,j} - \overline{\Delta S_{i,j}})^2} / (\frac{1}{mn}\Delta S) \qquad (3)$$

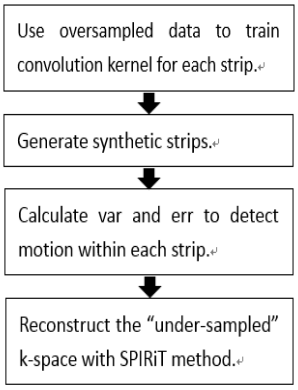

Fig 1. Schematic diagram of proposed motion correction

4. Discard the data in original k-space when its *var* or *err* is high. For all strips, synthetic strips are generated and used to detect motion when compared with original strips. Then, grid all strips into Cartesian coordinate to form a 2D arbitrary under-sampled k-space. Later a refilled k-space can be reconstructed from the under-sampled one using SPIRiT [3].

Simulation: Add motion to a T2-weighted abdominal image which is acquired with trigger on. Data size is 320×24×20×8 (fe×pe×strip×coil). Added motion is periodical expansion (average period is 4 seconds. One period can be divided into eight states with average expansion ratio: 1, 1.03, 1.05, 1.07, 1.03, 1.01, 1, 1.) to simulate continuous non-rigid motion caused by breathing. We also simulated the data acquisition process (TR=5000ms, TE=100ms) and then data from different motion states, which is consistent with acquisition time, are combined to form a simulated k-space. The proposed method is applied to the simulated k-space with a kernel size of 4×5. For comparison, we apply traditional COCOA method to the data with the same motion while data is acquired by turbo spin-echo acquisition with TR=3000ms, echo time=120ms, echo train length =16, calibration data is central 64 lines of k-space, kernel size is 4×5.

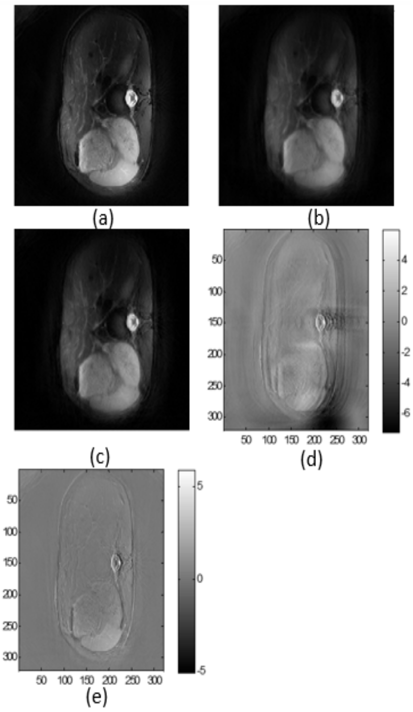

Fig 2. (a) is reference image with trigger on. (b) is image with simulated motion artifacts. (c) is motion corrected image using proposed method. (d) is the difference between (a) and (b). (e) is the difference between (a) and (c).

Results: Results of simulated data with proposed method and traditional COCOA method are shown in Fig.2 and Fig.3. According to Fig.2 and Fig.3, simulated motion can be effectively reduced with proposed method comparing to traditional COCOA.

Discussion: Different from traditional COCOA, our method discards the data in original k-space when its *var* or *err* value is high. As discussed in COCOA, data is less corrupted by random or continuous motion when both *var* and *err* are small [1], and data with less motion artifacts are left. PROPELLER trajectory reduces the motion between strips and provides a motion insensitive calibration for kernel training, which promotes the accuracy of later motion detection procedure. Thus, the combination of these two methods results in better correction of motion artifacts.

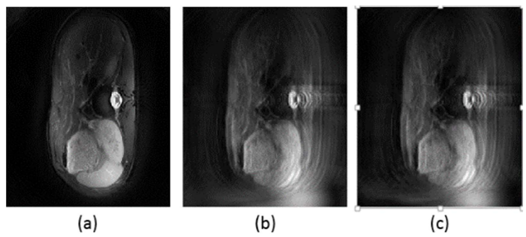

Fig 3. Results of traditional COCOA method. (a) is reference image acquired while trigger on. (b) is image with simulated motion artifacts. (c) is motion corrected image using traditional COCOA method in Cartesian coordinate.

Conclusion: Combining COCOA with PROPELLER and SPIRiT can effectively reduce non-rigid continuous motion in abdominal imaging, which is better than traditional COCOA.

Reference: [1] Huang Feng et al., Magnetic Resonance in Medicine, 2010, 64(1): 157-166. [2] Pipe, James G., Magnetic Resonance in Medicine, 1999, 42(5): 963-969. [3] Lustig et al., Magnetic Resonance in Medicine, 2010, 64(2): 457-471.